Principles of good monitoring

Kéry, M ; Schmidt, B R

Abstract: If monitoring follows certain rules, reliable conclusions can be made about the state of and changes in populations of the organisms concerned. Careful sample selection and minimisation of observational errors are key.

Originally published at:
Kéry, M; Schmidt, B R (2013). Principles of good monitoring. Hotspot, 28:8-9.

HOTSPOT

Measuring biodiversity

Research and practice in dialogue
Bulletin of the Swiss Biodiversity Forum
28 | 2013

Authors

Dr. Matthias Albrecht is an ecologist and researcher with the Agricultural Landscapes and Biodiversity Group at the Agroscope Reckenholz-Tänikon Research Station. He participates in the QUESSA project under the 7th Framework Programme of the EU. He focuses on biodiversity and ecosystem services in agro-ecosystems and approaches to support these.

Dr Ariel Bergamini is a botanist and heads the Ecosystem Dynamics research group at the Swiss Federal Institute for Forest, Snow and Landscape Research WSL as well as the programme "Monitoring the Effectiveness of Habitat Conservation in Switzerland". Further interests include conservation biology with respect to flowering plants and mosses.

Simon Birrer heads the Förderung der Vogelwelt (Support for birdlife) department at the Swiss Ornithological Institute and focuses on applied projects in farming and forestry.

Dr Stefan Eggenberg studied plant taxonomy and vegetation ecology and trained as a scientific draftsman. Formerly co-owner of the Atelier für Naturschutz und Umweltfragen (UNA) in Bern, he is currently Director of Info Flora, the national documentation and information centre for Swiss flora.

Dr Lisa Garnier holds a PhD in ecology. As science journalist, writer and project coordinator, she specialises on conveying biodiversity issues to the wider public. She maintains the Vigie-Nature blog of the French National Natural History Museum in Paris and develops interactive scientific experiments.

Christian Ginzler is a biologist with the Swiss Federal Institute for Forest, Snow and Landscape Research WSL. He heads the Remote Sensing research group and primarily works on aerial photograph interpretation, photogrammetry and image analysis as tools to measure landscape change.

Dr Yves Gonseth heads the Swiss Biological Records Center (CSCF) where he is in charge of maintaining contacts with field researchers (primarily entomologists) and cantonal and federal authorities in the areas of species and habitat protection and with relevant international institutions.

Anne-Laure Gourmand works at the French National Natural History Museum in Paris, developing science programmes for Vigie-Nature and implementing them with local stakeholders. She coordinates STELI, a programme to monitor dragonfly populations in France.

Dr Gabriela Hofer is a biologist in the Agricultural Landscapes and Biodiversity Group at Agroscope Reckenholz-Tänikon Research Station. She develops approaches to illustrate species and habitat dynamics in open cultural landscapes and identify the contributions of ecological compensation areas to maintaining species diversity.

Prof. Dr Rolf Holderegger teaches at the Swiss Federal Institute of Technology and heads the Biodiversity and Conservation Biology research unit at the Swiss Federal Institute for Forest, Snow and Landscape Research WSL. He is responsible for overall administration of the programme "Monitoring the Effectiveness of Habitat Conservation in Switzerland".

Dr Markus Jenny is a biologist at the Swiss Ornithological Institute where he is in charge of agricultural projects at the interface of research, implementation, markets and policy. He presides over the Vision Landwirtschaft association, a think-tank of independent experts on farming matters.

Dr Marc Kéry is a population ecologist at the Swiss Ornithological Institute. His research interests include large-scale modelling of species distribution and abundance, population models, and modelling measurement error processes in ecological field studies.

Dr Meinrad Küchler works in the Ecosystem Dynamics research group at the Swiss Federal Institute for Forest, Snow and Landscape Research WSL. He focuses on statistical data analysis and modelling ecological change in different habitat types in Switzerland.

Dr Enrique Lara is a researcher at the University of Neuchâtel where he studies micro-eukaryotes (algae, fungi and a variety of unicellular organisms). He is particularly interested in their evolutionary history, ecology, geographic distribution and their enormous diversity.

Dr Lukas Mathys is a biologist acting as project manager at the Sigmaplan AG consultancy. In a variety of projects, he deals with both substantive and technical aspects of the collection, evaluation and communication of biodiversity data.

Prof. Edward Mitchell has been in charge of the Soil Biology Laboratory of the University of Neuchâtel since 2009 and has co-managed the Neuchâtel Botanic Garden since 2011. His interests include the ecology and biodiversity of soil organisms with a focus on protozoa.

Dr Marco Moretti is an ecologist and team leader at the Swiss Federal Institute for Forest, Snow and Landscape Research WSL in Bellinzona. For the past ten years he has studied aspects of biodiversity and biocoenoses and their relationships to ecosystem processes and services along a range of environmental gradients as well as under laboratory conditions.

Prof. Jan Pawlowski heads the Laboratory for Molecular Evolution and Ecology of Protists of the Department of Genetics and Evolution at Geneva University. His research explores the evolutionary history of eukaryotes. He also manages the Swiss Barcode of Life (SwissBOL) network.

Dr Lukas Pfiffner is an agro-ecologist managing biodiversity and conservation projects at the Research Institute of Organic Agriculture FiBL with a focus on ecological systems optimisation and tritrophic interactions of arthropods and soil organisms in a variety of cropping systems.

Dr Benedikt Schmidt works at karch – the coordination centre for amphibian and reptile conservation in Switzerland – and leads a research group at Zurich University. By combining research and practical work he contributes to evidence-based conservation.

Dr Eva Spehn is on the scientific staff of the Swiss Biodiversity Forum and manager of the international Global Mountain Biodiversity Assessment network which maintains an online portal for biodiversity data for the world's mountain regions (www.mountainbiodiversity.ch). She is a member of the GBIF Swiss Commission and DIVERSITAS delegate to GBIF.

Dr Sibylle Stöckli is a project manager at the Research Institute of Organic Agriculture FiBL in the areas of biodiversity, climate change and ecosystem functions with a focus on entomology and crop protection.

Silvia Stofer heads the Biodiversity Assessment research group within the Biodiversity and Conservation Biology unit at the Swiss Federal Institute for Forest, Snow and Landscape Research WSL. Her responsibilities include maintaining the national data base of lichens in Switzerland (SwissLichens).

IMPRINT The Swiss Biodiversity Forum promotes the exchange of knowledge between biodiversity research, administrations, practitioners, policy-makers and wider society. HOTSPOT is one of the tools facilitating this exchange. HOTSPOT is published twice a year in German, English and French. It is available for download at www.biodiversity.ch. HOTSPOT 29I2014 will be published in May 2014 and will address the topic of Energy and Biodiversity. **Publisher:** © Forum Biodiversität Schweiz, Bern, November 2013. **Editors:** Dr Gregor Klaus (gk), Dr Daniela Pauli (dp). **Translation into English:** Christopher Hay. **Graphic design:** Esther Schreier, Basel. **Photos:** Photo credits are listed with the captions. **Printing:** Print Media Works, Schopfheim im Wiesental. **Paper:** Circle matt 115 g/m2, 100% recycled. **Print edition:** 3,300 copies in German, 1,100 copies in French, 1,000 copies in English. **Contact:** Forum Biodiversität Schweiz, Schwarztorstr. 9, CH–3007 Bern, Switzerland, Tel. +41 (0)31 312 02 75, biodiversity@scnat.ch, www.-biodiversity.ch. **Managing Director:** Dr Daniela Pauli. **Cost of production:** 15 CHF/copy.

Sharing biodiversity knowledge with all those who are interested in these matters is important to us. We would therefore like to continue to offer HOTSPOT free of charge. Any financial support will be greatly appreciated. HOTSPOT donations account: PC 30-204040-6. Manuscripts are subject to editorial revision. Authors' contributions do not necessarily reflect the opinions of the Swiss Biodiversity Forum.

sc | nat

Science and Policy
Platform of the Swiss Academy of Sciences

Swiss Biodiversity Forum

Cover (top to bottom):
1. Diverse micro-organisms (photo credit: Edward A. D. Mitchell); 2. Determining the diversity of fruit varieties (photo credit: ProSpecieRara Basel); 3. Archived butterfly diversity (photo credit: Beat Ernst Basel); 4. Biologists working in the field (photo credit: Edi Stöckli)

The scientific basis
Principles of good monitoring

Marc Kéry, Swiss Ornithological Institute, CH-6204 Sempach, marc.kery@vogelwarte.ch; Benedikt R. Schmidt, Koordinationsstelle für Amphibien- und Reptilienschutz in der Schweiz (karch), CH-2000 Neuchâtel, benedikt.schmidt@unine.ch

If monitoring follows certain rules, reliable conclusions can be made about the state of and changes in populations of the organisms concerned. Careful sample selection and minimisation of observational errors are key.

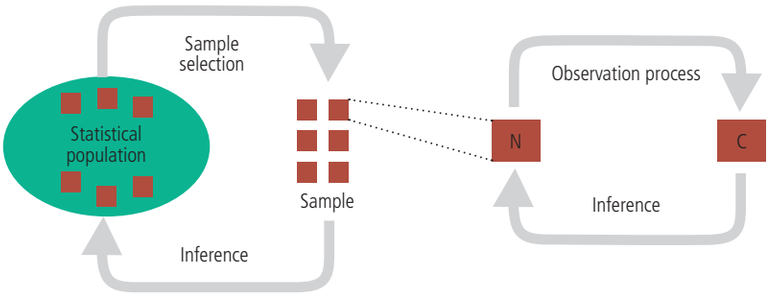


Fig. 1. Every assessment of biodiversity corresponds to a two-step sample survey N = Population; C = Count

Biodiversity is a very broad term encompassing the natural diversity of genes, individuals, populations, species, habitats and biocoenoses. In order to measure biodiversity one must first decide which of its aspects can be determined most usefully, precisely and cost-effectively. The population, i.e. the collection of all the organisms of the same species which live in the same geographical area, is of key significance. A population can most directly be described by its size, also known as abundance, followed by its distribution and by the patterns of abundance and distribution over time (trend). All three of these metrics are of key importance in biodiversity monitoring (Yoccoz et al. 2001). The principles described below are also relevant to species richness, another metric often used to describe biodiversity.

Distribution and abundance are often treated as separate measures even though distribution is simply a less informative summary of abundance: a species occurs at a location if its abundance is greater than zero. If a species' abundance in every location in a given area is known, then the species' distribution is also known, but the reverse is not true. Despite this equivalency it is often useful for practical reasons to treat these two measures separately, as data collection protocols and methods of statistical analysis may vary.

The laws of statistics

It is fundamentally important to recognise that biodiversity metrics such as abundance or distribution should be measured based on the principles of statistical sampling. This means that a researcher selects a proportion of the whole (called a sample), examines and describes it and then, based on the laws of statistics, draws conclusions (i.e. extrapolates or, in statistical terms, makes an inference) about the whole (the "statistical population") from which the sample was drawn. This is not simply a case of "nice to have" or of satisfying academic desires; the aim of this process is solely to ensure that reliable inference can be drawn about biodiversity.

Correcting observational errors

In stark contrast to sampling in other fields, such as economics or sociology, a researcher sampling populations of animals or plants almost always has to deal with systematic observational errors which mostly result from individuals or species remaining undetected. The probability of detecting species in the field is therefore usually smaller than 100% (Kéry 2008). Neither distribution nor abundance can be observed directly and without error. This trivial insight, familiar to anyone who spends time watching nature, has far-reaching implications for the type of sampling employed as well for data analysis. Whenever a researcher uses counts in the field in order to determine the absolute size of a population or the real occurrence of a species, this systematic observational error must be taken into account in the sampling procedure so as to be able to statistically eliminate it at a later stage.

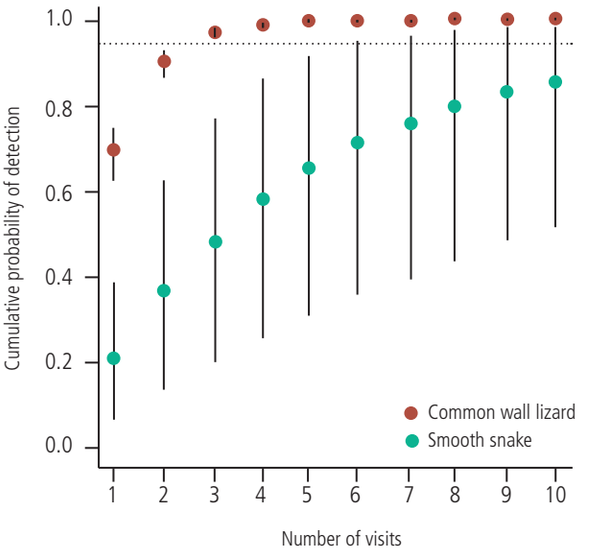
A numerical example

One has to imagine the measurement of biodiversity in a given area as a two-step sampling procedure (Fig. 1). The first step entails the definition of the statistical population about which inferences are to be drawn. This could be, for example, the total population of Great tits in Switzerland. A sampling unit is defined next (e.g. 1 km^2 squares) and a certain number is selected at random, resulting in an initial spatial sample. Each square hosts a population N that can be measured in a second step, e.g. by determining the number of Great tit territories (C). This count represents the second, nested sample. The observability of Great tits is smaller than 100%, therefore $C \leq N$. Consequently, statistical models must be employed to describe the observation process, so that an undistorted estimate of the status N in the sampling square can be derived from measuring C. In a further step the overall national population of Great tits can thus be projected. Let us take a simple numerical example and assume that we have randomly selected 1000 of the roughly 42,000 km^2 of the Swiss territory. Let us further assume that we found a total of 8000 Great tit territories in these 1000 squares and that on average 2 out of 10 territories would have been missed so that the territories' probability of detection in the sample C is 0.8, and that no other significant factors are associated with the observation process (e.g. duplicate counts). The Swiss Great tit population can therefore be projected to comprise ((8000:1000):0.8) $\times$ 42,000 = 420,000 territories. It is also important to calculate the confidence interval which indicates the reliability of the estimate.

The sample

The explicit portrayal of measuring populations and their distribution as a sam-

Fig. 2: Probabilities of detection for Common wall lizard and Smooth snake (incl. Bayesian confidence interval). The two species have different probabilities of detection per visit (approx. 0.7 and 0.2). If an area is visited multiple times, there is a cumulative probability of 0.95 that the Common wall lizard will normally be detected after three visits, given the species does occur in the area. A significantly greater number of visits will be needed for the Smooth snake. The necessary number of visits per site is scarcely affordable; the risk that the species will not be detected despite being present is high. This makes statistical methods worthwhile that correctly estimate abundance and distribution.



Smooth Snake. Photo credit: Thomas Ott, Bubendorf

pling process shows that the selection of both samples must follow certain rules to allow for conclusions to be drawn based on the laws of statistics. The most important principle to be applied in the first step is that of random sampling which is the only way to ensure that a representative sample is being obtained.

The adequate treatment of the observation process must also follow certain rules. There must be a certain degree of standardisation in measurements, for example with respect to spatio-temporal sampling, the method used, and the conditions under which observations are recorded. However, standardised methods alone are not sufficient to guarantee reliable measurements of biodiversity. Experience has shown that many other influences can not fully be eliminated (e.g. variation in the recorders' levels of experience or variation in population density) and that even in highly standardised monitoring programmes the probabilities of detection are not constant. Normally several site visits are needed to be able to estimate the probability of detection. A simplified example can illustrate this: If one finds a species known to occur in the area on the first visit but not on the second it can be said that the probability of detection is 0.5. Figure 2 shows empirical probabilities of detection for the Common wall lizard and the Smooth snake; the data were collected as part of the field work undertaken to update the 2005 Red list of reptiles.

Unfortunately most monitoring programmes show deficits in one or both of the sampling components described above. Very good examples of programmes explicitly taking account of both components are Biodiversity Monitoring Switzerland BDM (Weber et al. 2004) and the programme monitoring common breeding birds in Switzerland MHB (Kéry & Schmidt 2008). The work undertaken to update the red list of amphibians similarly observed the principles described above (see article on p.16). In all cases a random spatial sample was or is being surveyed multiple times per season using methods that allow for estimates of probabilities of detection and thus also of total populations and ranges. If the rules described above are followed, a monitoring programme will deliver good-quality information; this is also true for programmes relying on volunteers.

Conclusions

The principles of good monitoring are easily summarised. First one has to consider which question the monitoring programme is intended to answer. In the example used above the question was, "How many Great tits are there in Switzerland?" Next one has to decide which of the biodiversity metrics are suitable to answer this question. Abundance and distribution are metrics of practical relevance in our view. The following step involves careful sample selection and a data collection protocol that allows for unavoidable observational errors to be minimised, be it in the field or later in the course of data analysis. If the sample is taken at random and consideration is given to incomplete observability, then the monitoring programme will allow for reliable inference to be made, resulting in correct decisions being taken in conservation management.

References

biodiversity.ch/index.en.php > Publications